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CONSTRAINTS ON FILAMENT MODELS DEDUCED FROM DYNAMICAL ANALYSIS

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I. Introduction

The problems of prominence structure, support, and stability are of fundamental importance in understanding solar plasmas. The original theoretical work in this area was done by Kippenhahn and Schluter (1957), who theorized that prominence material was supported by a magnetic loop with a dip in the middle. A more recent model by Kuperus and Raadu (1973) envisions the prominence as being supported by an X type magnetic configuration with material condensing from coronal material. While there are several variations on these theories they represent the two basic concepts for prominences and both are treated basically as static, although the Kuperus and Raadu model could be extended to a dynamic concept.

The dynamic studies of prominences have been largely observational. Both upflows and downflows have been reported by various authors (see for example: Dunn, 1960; Engvold, 1976; Kubota, 1980; Martres et al., 1981; Malherbe et al., 1981 and 1983; Schmieder et al., 1985; Engvold et al., 1985; and Simon et al., 1986).

We present here the conclusions deduced from simultaneous observations obtained with the Ultra-Violet Spectrometer and Polarimeter(UVSP) on the Solar Maximum Mission satellite, and the Multichannel Subtractive Double Pass(MSPD) spectrographs at Meudon and Pic du Midi observatories. The observations were obtained in 1980 and 1984. All instruments have almost the same field of view and provide intensity and velocity maps at two temperatures (approximately $1.x10^5$K for CIV with the UVSP, and $1.x10^4$K for Hα with the MSDP). The resolution is ~0.5 to 1.5" for Hα and 3" for CIV. The high resolution and simultaneity of the two types of observations allow us to more accurately describe the flows in prominences as functions of temperature and position. The results put some constraints on the models and show that dynamical aspects must be taken into account.

II. Active Region Filaments

An active region filament, located in NOAA region 2697, was observed continuously on September 29 and 30, 1980 (see Schmieder et al., 1985). The filament was located near disk center appeared to consist of three extended, low lying loops limited by the footpoints marked A, B, C, and D in figure 1a. The filament lies along a neutral line of photospheric magnetic field, with the "footpoints" anchored in regions of enhanced positive magnetic field. The Dopplergrams obtained in Hα and CIV (figure 1b and 1d) show that material in the filament between the "footpoints" is blueshifted while at the "footpoints" material is redshifted.

The measured values of velocity are presented in tables 1 and 2. We note that during seven hours of observation on September 29, a particularly high steady flow was observed at "footpoint" A. These types of motions seem to be fairly typical of other motions observed in active region filaments.

Table 1 - Redshifts at the Footpoints (km/s)

Point	A	B	C	D
Hα	-9 to -12	-1 to -3	-1 to -6	-3 to -6
CIV	-2 to -10	-2 to -8	0 to -2	

Table 2 - Blueshifts between the Footpoints (km/s)

	A-B	B-C	C-D
Hα	2	1.5 to 3	0 to 2
CIV	5 to 10	5 to 10	10 to 25

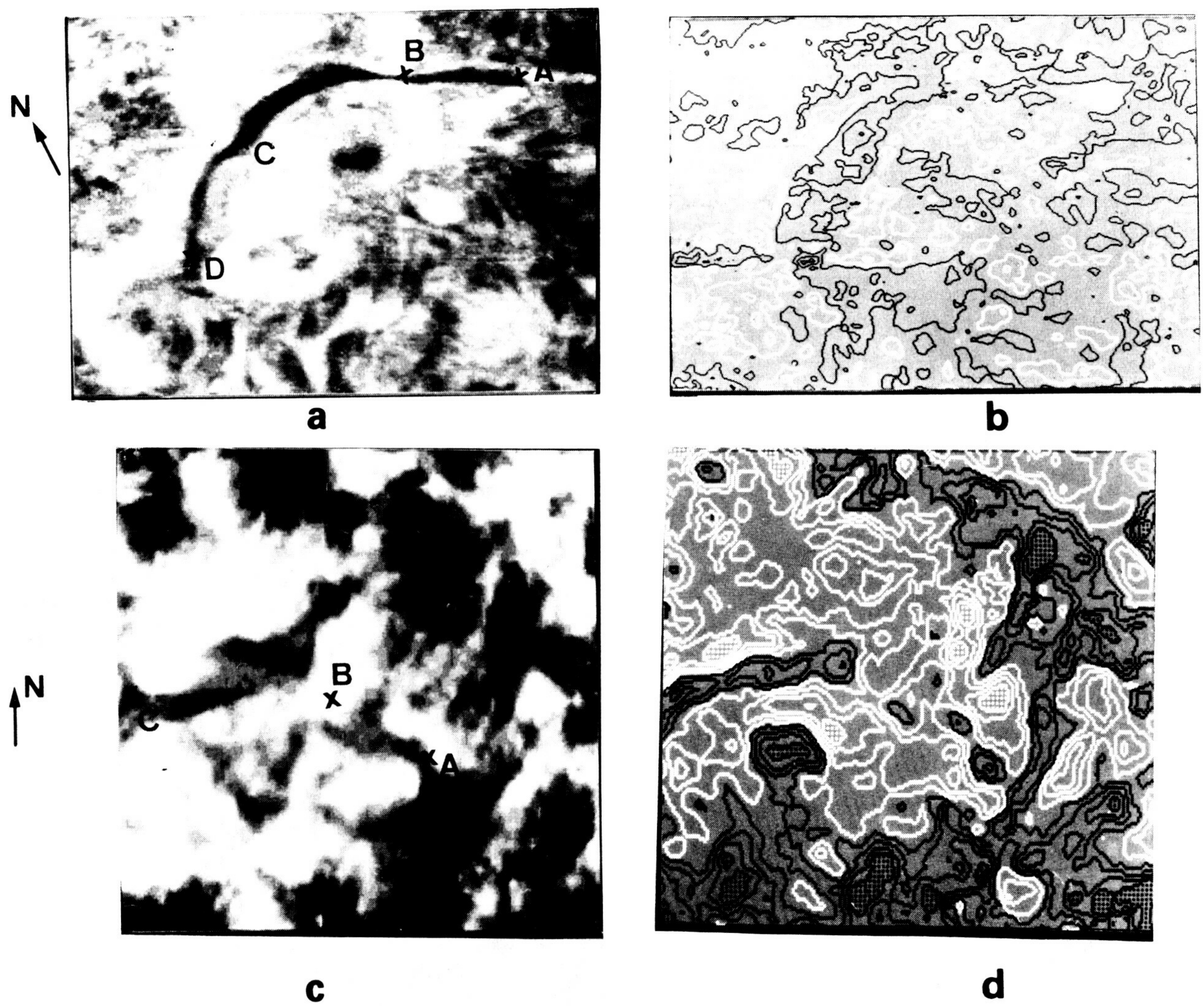

Figure 1. Intensity maps in Hα(a) and in CIV(c) lines, Velocity maps in Hα(b) and in CIV(d) of an active region filament (white contours correspond to red shifts)

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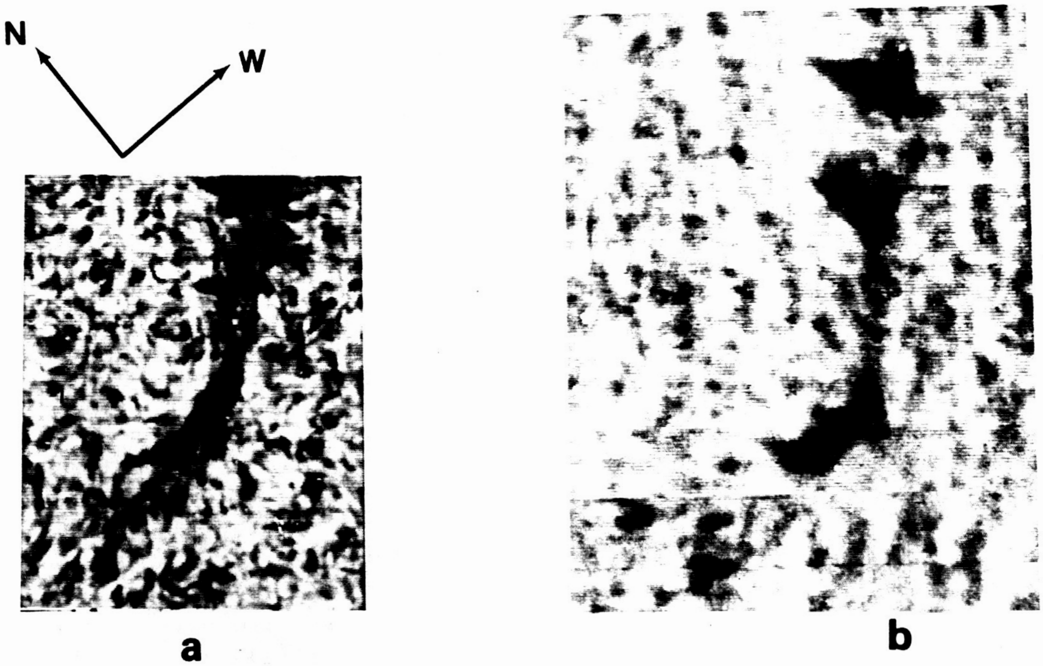

Figure 2: Hα images of a quiescent filament on October 15 (a), and October 17, 1984 (b).

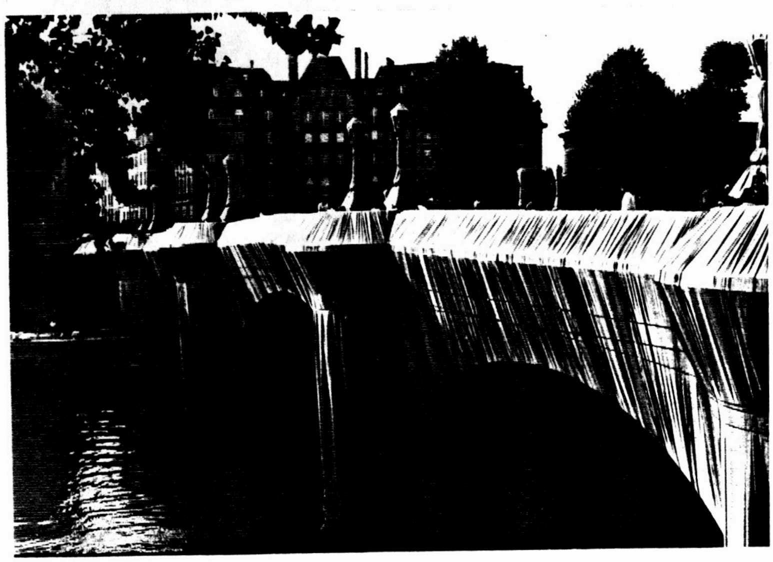

Figure 3: The Pont Neuf in Paris, wrapped by Cristo in June, 1985.

III. Quiescent Filament

Similar intensity and velocity measurements were made on a quiescent filament from October 15 through October 18, 1984. The objective of the study was to determine the three dimensional nature of the flows in Hα and CIV using the center-to-limb perspective effects.

Observations in Hα on October 17 (figure 2b) and later show a classical quiescent filament structure with footpoints connected by a large arch. This structure has an appearance similar to the Pont Neuf wrapped by Christo (figure 3). The fine structure of the filament could be seen with the very good seeing available at Pic du Midi on October 15, 1984. This revealed that the large loops were actually composed of many small scale loops with typical radii of 1000km. These small scale loops seemed to be arranged in a cluster at the footpoints, and somewhat better aligned between them.

Velocity measurements showed that there was no coherent velocity pattern along the filament. The velocities in Hα ranged from 2 to 5km/s on October 15 and were smaller on the other days. However, the reduced velocities are most likely due to the smearing effect from bad seeing. The comparison of Hα and CIV velocities was also inconclusive.

A statistical study of the velocities in the field of view in and near the filament gives an idea of the structure of the velocity. The standard deviations of the velocities in the filament are compared to the whole field of view (2'x2') as functions of time. These are presented in figure 4 for several different satellite orbits over several days. Near disk center the values are greater in the filament than in the mean transition region around it, while the opposite situation occurs near the limb (see figure 5), although both values decrease. Measurements of the Doppler broadening of the line show the same effect, which indicates that the large scale (>3") and the small scale (<3") velocity structure have the same behavior. From these measurements we deduce that the vertical velocities are greater than the horizontal ones by a factor of 3 in the filament and 2.5 outside(Simon et al., 1986).

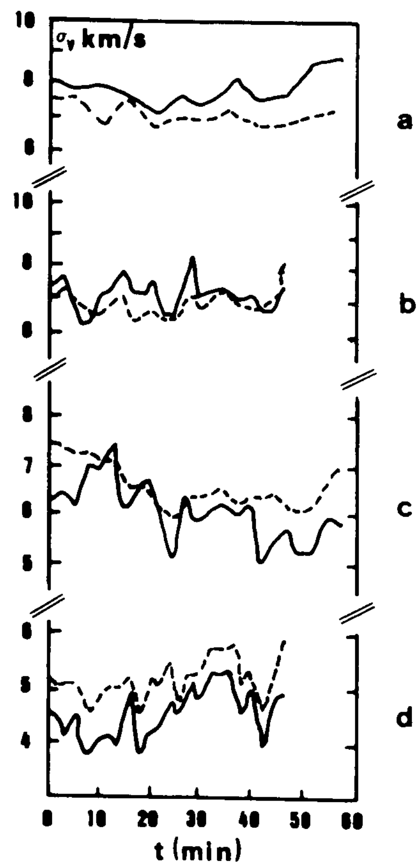

Figure 4. Velocity standard deviation calculated for each frame during the SMM orbit, on October 15, 16, 17, and 18, 1984 (resp. a,b,c, and d). solid lines are for the filament area data and the dashed ones for the 2'x2' area dat.

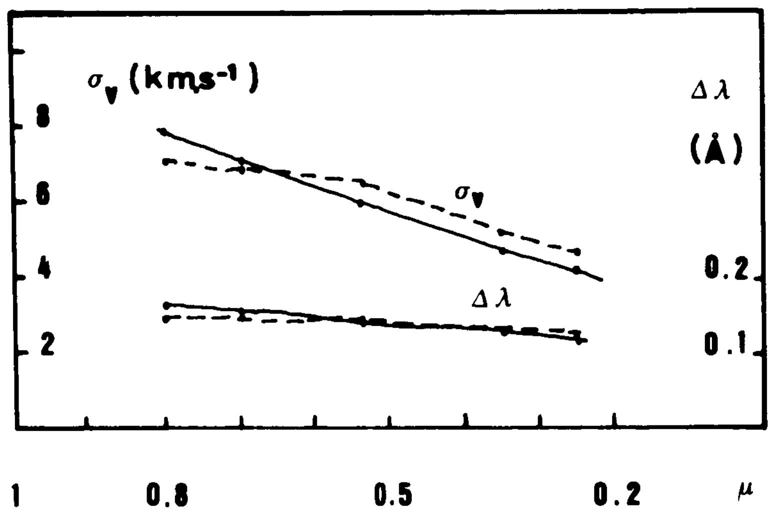

Figure 5. Variation of the velocity standard deviations (σ_V) and of the Doppler linewidth ($\Delta\lambda$) of the CIV line versus μ.

IV. Conclusion

The observations of the active region filament pointed out a reasonable model for this type of prominence. The downward velocity at the footpoints with the upward velocity between suggests a model with a long magnetic flux rope with material slowly draining out at the footpoints. As the total mass in the loop decreases it allows the central part to rise. The problem with this model is that the small pressure scale height should make the prominence drain much more rapidly than is observed.

The quiescent filament observations do not seem to provide any insight into the validity of either the Kippenhahn-Schluter or Kuperus-Raadu models for prominences. The observations seem to indicate that there are no really significant flows, and the structure consists of many small scale loops. Time observations seem to indicate that dynamic models may be more appropriate for describing prominences. Although a dynamic model has been presented by Poland and Mariska (1986), the time scales indicated by the calculations seem to be too long for the observations.

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